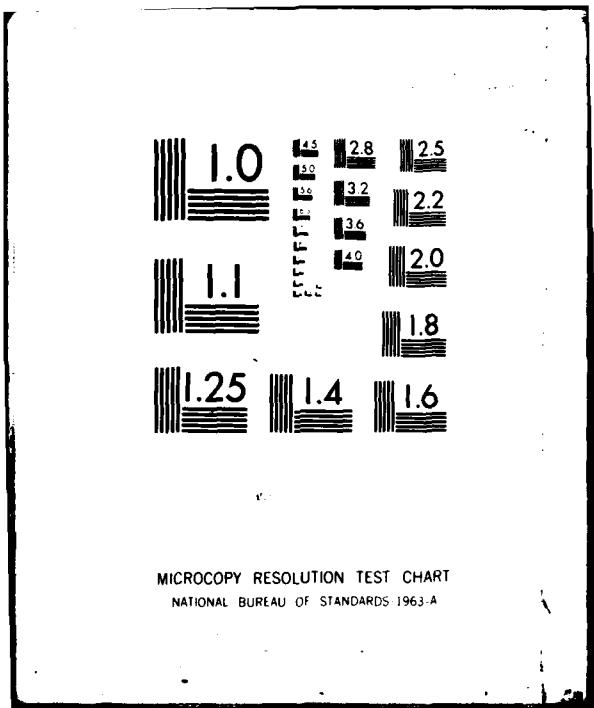


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A PROXIMITY EFFECT CORRECTION PROGRAM FOR ELECTRON BEAM LITHOGR--ETC(II)  
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RESEARCH AND DEVELOPMENT TECHNICAL REPORT

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A PROXIMITY EFFECT CORRECTION PROGRAM FOR ELECTRON  
BEAM LITHOGRAPHY

H. L. BERKOWITZ  
R. A. Lux  
ELECTRONICS TECHNOLOGY & DEVICES LABORATORY

JANUARY 1982

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## INTRODUCTION

Electron beam lithography is the highest resolution technique in use for patterning the resists used in integrated circuit processing. The practical resolution of this technique is not limited by the primary electron beam, which can readily be focused to a spot size of less than 1000Å<sup>1</sup> or by the inherent resolution of the resist,<sup>2</sup> but rather by scattering of the electrons. This scattering, both within the resist (forward and lateral) and from the substrate, results in a transverse flux of electrons (perpendicular to the beam) whose magnitude depends on the energy of the beam, the resist thickness, and the atomic number of the resist and substrate. This transverse electron flux exposes the resist in regions adjacent to that actually addressed by the e-beam writing pattern which results in a geometrical distortion in going from the e-beam writing pattern to the resulting developed pattern in the resist. This geometrical distortion is commonly known as proximity effect.

## DOSE SPREAD

The pattern produced in the resist is the cumulative effect of the electron beam spread, the energy deposition in the resist, and the action of the developer on the resist. Some of the processes have been analyzed in detail. However, for purposes of understanding proximity effect it is sufficient to use a simplified model.

The dose spread is approximated by the sum of two Gaussians with characteristic widths  $\beta_f$  and  $\beta_b$ , related respectively to the spread due to forward- and backward-scattered electrons. The dose delivered to a resist at a point on the resist substrate interface by an electron beam incident at  $r = 0$  is then

$$f(r) = k \left( \frac{1}{\beta_f^2} \exp \left( -\frac{r^2}{\beta_f^2} \right) + \frac{n}{\beta_b^2} \exp \left( -\frac{r^2}{\beta_b^2} \right) \right), \quad (1)$$

where  $k$  is a constant and  $n$  is the ratio of integrated contribution of back-scattered to forward-scattered electrons. The resist is assumed to be developed in any region where the dose exceeds a critical dose  $D_c$ . Therefore, the resulting pattern in the resist created by a pencil beam will be that region defined by  $f > D_c$ . Typical values of the parameters obtained by Monte Carlo calculations of electron transport are shown in Table 1.

1. Murrae J. Bowden, "The Physics and Chemistry of the Lithographic Process," *J. Electrochem. Soc.* 128, 195 C (1981)
2. Alec N. Broers, "Resolution Limits of PMMA Resist for Exposure with 50 kV Electrons," *J. Electrochem. Soc.* 128, 166 (1981)

TABLE 1

PARAMETERS THAT DEFINE  $f(r)$  EVALUATED AT THE RESIST-SILICON INTERFACE FOR PMMA RESIST OF THICKNESS  $t$ .

E-beam (keV)	$t$	$\beta_f$	$\beta_b$	$n$
10	0.5	0.22	0.65	0.51
15	0.5	0.13	1.14	0.51
15	1.0	0.44	1.41	0.52
25	0.5	0.06	2.6	0.51
25	1.0	0.22	2.9	0.49
40	0.5	0.04	6.0	0.42
40	1.0	0.11	6.0	0.45

The parameters are not known to high accuracy. Other estimates, both from calculation and experiment, differ by as much as a factor of two<sup>3</sup> in some cases. Parikh<sup>4</sup> suggests that  $\beta_f = .1$ ,  $\beta_b = 2.5$ ,  $n = .9$  are useful estimates for PMMA with  $t \approx .5\mu$  and electron energy  $E_b = 25$  kV. The dose at any point in a plane is obtained by integration of  $f$  over all source points addressed by the electron beam. If the incident electron beam is not ideal but has a Gaussian spread of width  $\beta$  beam, Equation (1) is modified by using effective widths  $\beta_b^*$  and  $\beta_f^*$  which are given by

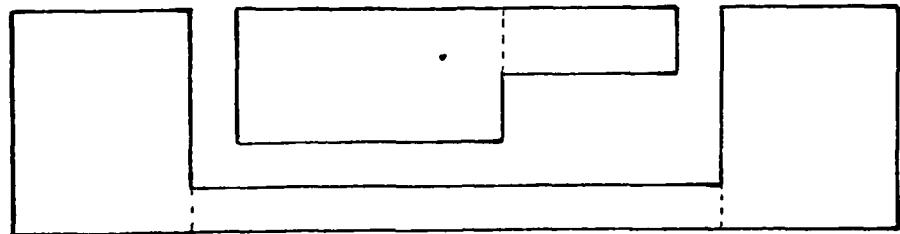
$$\beta_{b,f}^{*2} = \beta_{b,f}^2 + \beta_{\text{beam}}^2. \quad (2)$$

In practice, the beam width will be much smaller than  $\beta_b$  and comparable to  $\beta_f$ , so that only  $\beta_f$  need be replaced by its effective value.

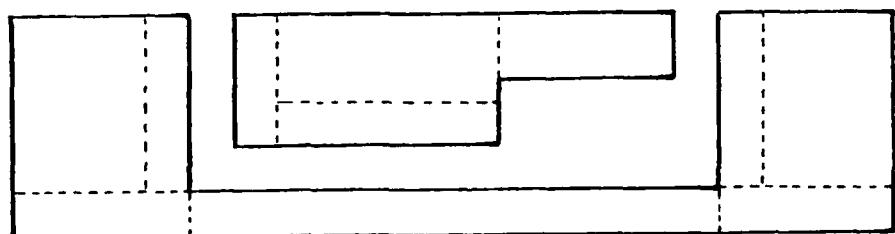
#### CORRECTION PROCESS

The fundamental problem of a proximity correction process is to arrange that the contour line  $D = D_C$  matches a desired pattern. A convenient scheme for accomplishing this is to set the written pattern to the desired pattern and adjust the e-beam exposure within the pattern to achieve the desired contour. Various techniques have been proposed to this end. We will discuss one such technique, the self-consistent technique, proposed by Parikh,<sup>5</sup> which forms the basis of our correction algorithm. In this technique the desired pattern is divided into a collection of  $N$  elements, such as shown in Figure 1, each of which is given a uniform exposure. The exposures  $E_i$  are chosen so that the average dose in each element is

3. Mihir Parikh and David Kyser, "Energy Deposition Functions in Electron Resist Films on Substrates," *J. Appl. Phys.* 50, 1104 (1979)
4. Mihir Parikh, "Proximity Effects in Electron Lithography: Magnitude and Correction Techniques," *IBM J. Res. Develop.* 24, 438 (1980)
5. Mihir Parikh, "Corrections to Proximity Effects in Electron Beam Lithography," *J. Appl. Phys.* 50, 4371, 4378 (1979)



(a)



(b)

**Figure 1.** Division of a pattern into (a) 5 and (b) 11 elements.

the same. The average dose in element A is given by the double integral over element areas,  $S_A$  and  $S_i$ ,

$$D_A = \frac{1}{S_A} \sum_i k E_i \int_{A,i} \int_{S_A} ds_A ds_i \left( \frac{1}{\beta_f^2} \exp \left( \frac{-(\vec{r}_A - \vec{r}_i)^2}{\beta_f^2} \right) + \frac{n}{\beta_b^2} \exp \left( \frac{-(\vec{r}_A - \vec{r}_i)^2}{\beta_b^2} \right) \right), \quad (3)$$

where the sum over all elements i include the element A. Setting the average doses equal results in a set of N linear equations for the exposures.

A computer program, PROXR, implementing the self-consistent correction technique, has been written. The program accepts as input the coordinates of the elemental rectangles into which the pattern is partitioned. The specialization to rectangular figures was made for two reasons, (a) the integrals to determine average dose can be done analytically, involving functions no more complex than the sums and products of error functions,<sup>5</sup> and (b) the ET&D Laboratory LEBES-D E-beam System is a vector write machine which most naturally writes in a rectangular pattern. The output of the program is a set of relative exposures for the elemental rectangles. Further diagnostics built into PROXR allow the dose to be calculated at selected points in the pattern, arranged either in an 11 x 11 window or in 101 points equally spaced along a line.

The program is written in interactive form so that the user chooses partitioning of the pattern, and can immediately display predicted doses at selected points in the pattern. For partitioning into N elemental rectangles, the calculation time increases as  $N^2$ ; hence, there is incentive to partition only as necessary to achieve adequate correction. At the present time it does not seem feasible to do automatic partitioning without exercise of some judgment.

#### OPERATION OF PROXR

Written in FORTRAN 7, PROXR is an interactive program which implements the self-consistent proximity effect correction scheme. PROXR is currently running on the Fort Monmouth Interdata 8/32 time sharing system.

##### Files Required

LU0 is assigned to the user's console

LU1 is an input file of a maximum of 100 user-defined pattern rectangles

LU2 is an output file to which simulated dose calculations are written

LU3 is an output file to which the description of the rectangles and their relative exposures are directed.

Any or all of the above may be assigned to the user's console.

##### Input Required

PROXR reads from LU1, a user-defined file of elemental rectangles written in free-form format. Each rectangle is designated by four numbers indicating x-low, x-high, y-low, y-high, separated by commas, blanks, or carriage returns. The reading sequence is terminated by an END OF FILE or an illegal character.

The proximity parameters BF, BB, ETA, ISO, IREF are requested from LU0, the user's console, and are described as follows:

5. Mihir Parikh, "Corrections to Proximity Effects in Electron Beam Lithography," J. Appl. Phys. 50, 4371, 4378 (1979)

BF and BB are, respectively, the effective forward and backscattering width as defined in Equation (3). All dimensions (the coordinates of the elemental rectangles and the scattering widths) must be in the same units, preferably micrometers.

ETA is the backscatter fraction, ISO is an integer  $\geq 0$ . If ISO is equal to zero then all exposures are set equal to one and no corrections are made.

If ISO is greater than 0 then ISO sets the number of iterations used in solving the linear equations by the subroutine SOLGS. A value of 4 is usually enough to ensure convergence in SOLGS.

IREF is an integer  $\geq 0$ . If IREF = 0 then IREF is the record number of a record in LU1 to which the exposure value 1 will be assigned in normalizing the exposure array EXPO2. If IREF = 0 then EXPO2 is equated to EXPO1. During operation, the program will supply the necessary prompts for all further input.

After reading the rectangle coordinates and the start-up parameters, PROXR calculates A (I,J), the influence matrix, the elements of which are the average dose in Area I due to unit exposure in Area J. Provisions are made to set insignificant matrix elements of A (I,J) to zero. The average doses in the rectangles are equated, and the linear system is solved using a Gauss-Seidel iterative subroutine, SOLGS. The exposures thus calculated are stored in EXPO1, normalized so that the exposure given to large figure is one. They are also stored EXPO2 renormalized so that the exposure in a user-defined figure is unity.

Once the exposures for each elemental rectangle have been determined, PROXR will calculate the dose delivered at an array of points specified by the user by calling one of the two simulation subroutines WINDOW or LINE. If WINDOW is specified, values of the dose are calculated on a grid of 11 x 11 points equally spaced between the limits x-low, x-high, y-low, and y-high. If LINE is selected, the dose is calculated at 101 points equally spaced between the points  $(x_1, y_1)$  and  $(x_2, y_2)$ . In either case, the dose is normalized so that the dose calculated at the center of a large rectangle is  $1 + n$ , as would be expected on giving this feature unit exposure. The simulations continue until the user requests it be terminated, at which time new start-up parameters can be entered or the program terminated. A sample PROXR conversation illustrating the above is included in the Appendix.

## RESULTS OF CALCULATIONS

We have used PROXR to calculate exposures and simulate the predicted dose distribution for a variety of test patterns. We present three cases which illustrate situations for which proximity effect corrections are essential.

Recommended exposures for five isolated figures are shown in Table 2 for two values of  $\beta_f^*$ . The wide spread in recommended exposures illustrates the futility of attempting to write patterns with large and small features using a single exposure value. We also note the relative insensitivity of large figures to changes in  $\beta_f^*$ .

TABLE 2. RELATIVE EXPOSURE OF ISOLATED FIGURE CALCULATED FOR  $n = 0.8$ ,  $\beta_b = 3.0$ ,  $\beta_f^* = 0.1, 0.3$ .

<u>Figure</u>		Relative Exposure	
		$\beta_f^* = 0.3$	$\beta_f^* = 0.1$
Square	$20 \times 20 \mu\text{m}$	1.09	1.08
Square	$5 \times 5 \mu\text{m}$	1.40	1.36
Square	$1 \times 1 \mu\text{m}$	2.51	1.96
Square	$0.5 \times 0.5 \mu\text{m}$	4.05	2.27
Rectangle	$1 \times 15 \mu\text{m}$	1.89	1.68

When the pattern consists of more than one figure with spacing close enough to allow interaction, the predicted exposure depends upon the location of the figure. The exposures for a chessboard pattern with  $1 \mu\text{m}$  squares is shown in Figure 2.

A more complex pattern is shown in Figure 3 where the actual dose distribution along a selected line is shown for corrected and uncorrected exposures. The overall reduction in dose seen in the uncorrected pattern would result in poor feature definition; the degradation being especially severe for the right-most stripe.

	2.08		1.98		2.00		2.19
2.08		1.82		1.78		1.89	
	1.82		1.68		1.72		2.00
1.98		1.68		1.65		1.78	
	1.78		1.65		1.68		1.98
2.00		1.72		1.68		1.82	
	1.89		1.78		1.82		2.08
2.19		2.00		1.98		2.08	

Figure 2. Exposures for a chessboard pattern of 1  $\mu\text{m}$  squares;  
 $\eta = 0.8$ ,  $\beta_b^* = 3.0$ ,  $\beta_f^* = 0.3$ . Exposure for a 1  $\mu\text{m}$  isolated square = 2.51.

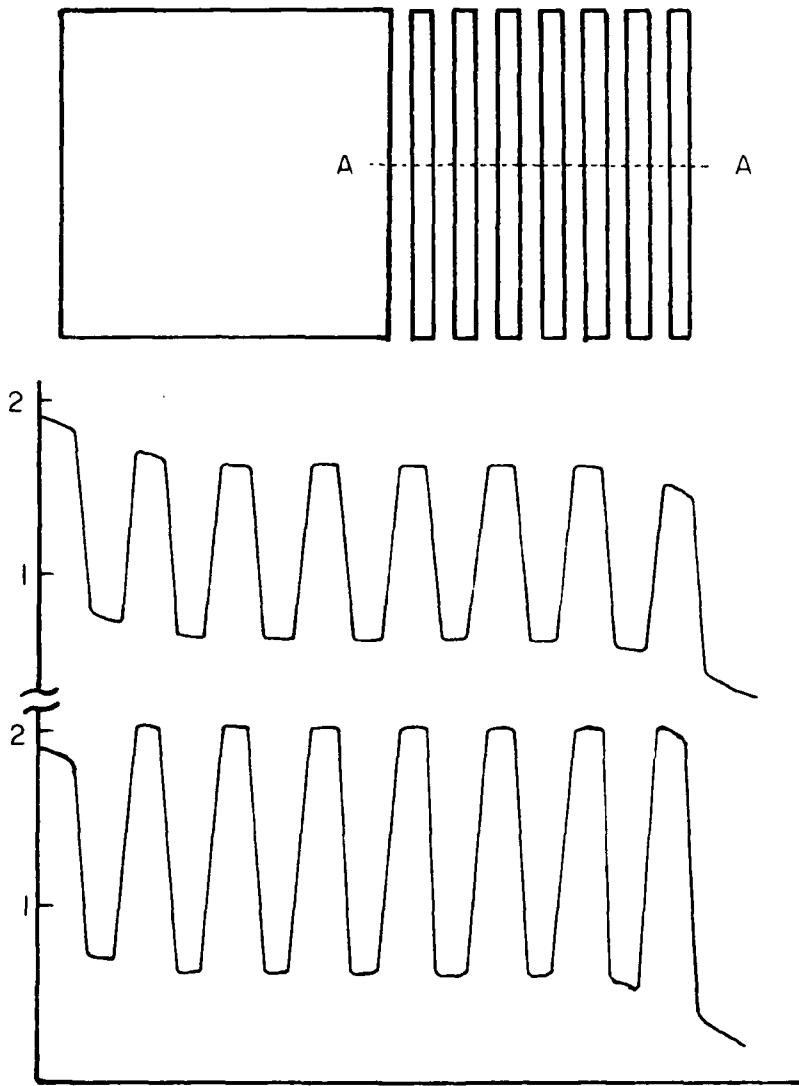


Figure 3. Dose along line A-A for corrected and uncorrected exposures;  
 $\eta = 0.90$ ,  $\beta_b = 2.5$ ,  $\beta_f^* = 0.1$ . Corrected exposures are square: 1.09,  
 Stripes: 1.38, 1.39, 1.39, 1.39, 1.38, 1.41, 1.54.

APPENDIX: LISTING OF PROXR

Variable List: MAIN

XY - An array containing the coordinates of the rectangles to be processed in the form

XY(1,\*) = x-low

XY(2,\*) = x-high

XY(3,\*) = y-low

XY(4,\*) = y-high

AREA - An array of areas of each of the above rectangles

A - An array of influence coefficients

EXPO1 - An array of exposures normalized so that exposure of a large figure is unity

EXPO2 - An array of exposures normalized so that exposure of a user defined figure is unity

NREF - Index of the reference rectangle in file

NREC - Number of rectangles to be processed

NRECI - NREC + 1

BF - Effective forward scatter width

BB - Backscatter width

ETA - Backscatter fraction

ISO - Number of times the Gauss - Seidel linear system solver is to be iterated or if ISO = 0 no corrections are made, and doses for equal exposure in all figures can be calculated.

## SUBROUTINES AND FUNCTION SUBROUTINES

LINE - Subroutine: calculates the simulated dose at 101 equally spaced points along a user-defined line segment.

WINDOW - Subroutine: calculates the simulated dose at 121 points in a user-defined rectangular window.

ERFXY - Real function: evaluates the integral

$$\int_{x_1}^{x_2} \int_{x'_1}^{x'_2} \frac{dx}{\beta} dx' \exp - \left( \frac{(x - x')^2}{\beta^2} \right)$$

ERF - Real function: calculates

$$\int_0^x \exp (-t^2) dt$$

ERFINT - Real function: calculates

$$\int_0^x \operatorname{erf}(t) dt$$

SOLGS - Subroutine: linear system solver using Gauss-Seidel recursive technique.

LISTING OF PROXR

```

1      C PROXR.FTN REVISED JEP 6 81
2      C FORT MONMOUTH PROXIMITY EFFECT PROGRAM
3      C MAIN PROGRAM SECTION
4          REAL XY(4,100),AREA(100),R(100,100),EXP01(100)
5          REAL EXP02(100)
6          DATA EXP02/100*0.
7
8      C XY(1,*)=X LOW,XY(2,*)=Y HIGH,XY(3,*)=X LOW,XY(4,*)=Y HIGH
9
10     C A IS THE AUGMENTED INFLUENCE MATRIX
11     C EXP01(I,J) IS THE EXPOSURE OF THE ITH RECTANGLE RELATIVE TO THAT OF
12     C A PROPERLY EXPOSED, ARBITRARILY LARGE RECTANGLE.
13     C EXP02(I,J)=EXP01(I,J)/EXP01(1,1)
14
15     DO 1 I=1,100
16         PERI(I,1)=EXP01(I,1)+EXP01(I,2)+EXP01(I,3)+EXP01(I,4)
17         PERI(I,2)=EXP01(I,1)+EXP01(I,4)+EXP01(I,5)+EXP01(I,6)
18         CONTINUE
19         I=101
20         NREC=I-1
21         NREC1=1
22
23     C NPEC IS THE NUMBER OF RECTANGLES TO BE PROCESSED
24     200 FORMAT(1X, ENTER BF,BE,ETA,I00,IREF)
25     WRITE(0,200)
26     PERI(0,1)=BF,BE,ETA,I00,IREF
27     IF (I00<0) THEN
28
29     C INITIALIZE A
30         DO 4 I=1,NPEC
31             A(I,NREC1)=1
32             DO 4 J=1,NPEC
33                 A(I,J)=0
34
35     C CALCULATE THE INFLUENCE MATRIX
36
37         DO 6 I=1,NPEC
38             DO 6 J=I,NPEC
39                 A(I,J)=
40                     1.*EFXY(XY(1,I),XY(2,I),XY(3,I),XY(4,I),J,BF)
41                     2.*EFXY(XY(3,I),XY(4,I),XY(5,I),XY(6,I),J,BF)
42                     3.*EFXY(XY(1,I),XY(2,I),XY(4,I),XY(5,I),J,BE)
43                     4.*EFXY(XY(3,I),XY(4,I),XY(5,I),XY(6,I),J,BE)
44                     5.*ETA*PERI(I,J)*AREA(J)
45
46                 A(J,I)=A(I,J)
47                 CALL SOLG(NPEC,NREC1,A,EXP01,I00)
48                 DO 7 I=1,NPEC
49                     EXP01(I)=EXP01(I)+1+ETA*AREA(I)
50                     CONTINUE
51                     IF (IREF==0) THEN
52                         PEF=1.
53                     ELSE
54                         PEF=EXP01(IREF)
55                     ENDIF
56
57                     DO 8 I=1,NPEC
58                         EXP02(I)=EXP01(I)-PEF
59                     ELSE
60                         DO 10 I=1,NPEC
61                             EXP02(I)=1.
62                         EXP01(I)=1.
63                         ENDIF ; I00 <> 0
64
65                     300 FORMAT('1X,' BF='1,610.2,' BE='1,610.2,' ETA='1,610.2,' I00='13,
66                         1 ' NPEC='13,' IREF='13)
67                     400 FORMAT(6X,'X LOW',T16,'X HIGH',T27,'Y LOW',T36

```

```

61      1 , 'Y HIGH', T47, 'EXP01', T57, 'EXP02'
62      500  FORMAT(1X,6,F10.2)
63      WRITE(3,300,BF,BB,ETA,ICO,NPEC,IREF
64      WRITE(3,400)
65      DO 11 I=1,NPEC
66      WRITE(3,500,' XY(I,J), J=1,4), EXP01(I), EXP02(I)
67      11  CONTINUE
68      700  FORMAT(' ENTER 1 FOR WINDOW, 2 FOR LINE, OTHERWISE 0')
69      2   CONTINUE
70      WRITE(0,700)
71      READ(0,♦)ICIM
72      IF(ICIM==1)CALL WINDOW(XY,NPEC,BF,BB,ETA,EXP01)
73      IF(ICIM==2)CALL LINE(XY,NPEC,BF,BB,ETA,EXP01)
74      IF(ICIM==1)OF_ICIM=3 GO TO 2
75      600  FORMAT(' ENTER 1 TO CONTINUE, 0 TO END')
76      WRITE(0,600)
77      READ(0,♦)NEXT
78      IF(NEXT.EQ.1) GO TO 2
79      STOP
80      END
81      SUBROUTINE WINDOW(XY,NPEC,BF,BB,ETA,EXP01)
82
83      C      REAL XY(4,100),EXP01(100),D(8,11),YR(11),D(11,11)
84      C SIMULATION SECTION
85      700  FORMAT(1X, 'ENTER THE WINDOW EDGES X1,X2,Y1,Y2')
86      11  CONTINUE
87      WRITE(0,700)
88      READ(0,♦)X1,X2,Y1,Y2
89      D=X2-X1+10
90      D=Y2-Y1+10
91      DO 9 I=0,10
92      XA(I+1)=X1+I*D
93      YA(I+1)=Y1+I*D
94      9   CONTINUE
95      DO 10 I=1,11
96      X=XA(I)
97      DO 10 J=1,11
98      Y=YR(J)
99      D(X,I)=DOIE(X,Y,XY,NPEC,BF,BB,ETA,EXP01)
100     10  CONTINUE
101     800  FORMAT(1X,F6.2,EX,11F6.2)
102     400  FORMAT(1X,' T30,"DOIE AT (X,Y)"')
103     900  FORMAT(1X,6X,'Y= ',11F6.2)
104     500  FORMAT(' X EDGES AT X= F6.2," F6.2," AND Y= ",F6.2," F6.2')
105     600  FORMAT(' ENTER 1 FOR NEW WINDOW OR 0 TO CONTINUE')
106     WRITE(2,500)X1,X2,Y1,Y2
107     WRITE(2,400)
108     WRITE(2,900)YR
109     WRITE(2,800)XA(I),D(X,I),J=1,11),I=1,11)
110     WRITE(0,600)
111     READ(0,♦)NEXT
112     IF(NEXT.EQ.1)GO TO 11
113     RETURN
114     END
115     SUBROUTINE LINE(XY,NPEC,BF,BB,ETA,EXP01)
116     C      REAL XY(4,100),EXP01(100),D(10,11)
117     DATA D/110*0./
118     C SIMULATION SECTION
119     700  FORMAT(1X,'ENTER THE LINE END POINTS X1,Y1 X2,Y2')

```

```

181      11  CONTINUE
182      WRITE(0,700)
183      READ(0,*)X1,Y1,X2,Y2
184      DX=(X2-X1)/100
185      DY=(Y2-Y1)/100
186      DO 10 IJ=0,100
187      I=IJ/10+1
188      J=IJ-10*(I-1)+1
189      X=I+DX+IJ
190      Y=(I+DY)*IJ
191      DO 10 I=DOE,...,11,1*PEC*EF*PI*ETA*EXP01
192      CONTINUE
193      500  FORMAT(1H*,1E+1...10E1.2)
194      500  FORMAT(1H*, T30.1'DE AT POINTS ON LINE 1, T+10E1)
195      500  FORMAT(1H*, F1= .EFF1.E, 2= .EFF2.E, 3= .EFF3.E)
196      WRITE(0,500)X1,Y1,X2,Y2
197      WRITE(0,500)I,I=0,11
198      WRITE(0,500)10*(I-1)+IJ,I=1,10,I=1,11
199      600  FORMAT(1H*, ENTER 1 FOR NEW LINE,0 TO CONTINUE )
200      WRITE(0,600)
201      READ(0,*)NEXT
202      IF (NEXT.EQ.1) GO TO 11
203      RETURN
204      END
205      REAL FUNCTION EFF(X)
206      ! THIS FUNCTION USED TO CALCULATE THE INFLUENCE MATRIX
207      ! EFF(X)=EFFINT(X)-EFFINT(X-1). IF !EFFINT(X) > 4-5*E !
208      ! +EFFINT(X-1)-1 E !EFFINT(X-1)-EFFINT(X-2)-E !
209      ! RETURN
210      END
211      FUNCTION EFF1()
212      ! EFF1=EFF(X)
213      REAL*8 X1,T,U
214      X1=REC(X)
215      IF (X1.GE.2.3) THEN
216      U=1
217      ELSE
218      T=1/(1+(X1*.47047))
219      U=(1.7478556*T-.958793E-1)*T+.343024)*T
220      U=1-U*EXP(-1*X)
221      ENDIF
222      EFF1=SIGN(1.,X)*U
223      RETURN
224      END
225      FUNCTION EFFINT(X)
226      ! EFFINT CALCULATES THE INTEGRAL OF EFF(X).
227      REAL*8 X1,T,U
228      X1=REC(X)
229      IF (X1.GE.1.5) THEN
230      U=X1
231      ELSE
232      T=1/(1+(X1*.47047))
233      U=(1.7478556*T-.958793E-1)*T+.343024)*T
234      U=X1-(X1*U-.5641896)*EXP(-1*X)
235      ENDIF
236      EFFINT=U
237      RETURN
238      END
239      SUBROUTINE SOLGS(N,N1,A,X,M)
240      ! TO USE THIS N1 MUST BE N+1

```

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181      REAL A(100,101),X(100)
182      C SETUP TRAIL X
183      DO 5 I=1,N
184      X(I)=0
185      DO 6 J=1,N
186      X(I)=X(I)+A(I,J)
187      X(I)=1-X(I)
188      NM1=N-1
189      C FORWARD IMPROVE
190      DO 4 IM=1,M
191      DO 10 I=1,N
192      A(I)=A(I,N1)
193      DO 20 J=1,N
194      IF (I.NE.J).AND.(A(I,J).NE.0) A(I,J)=A(I,J)+X(J)
195      30 CONTINUE
196      X(I)=X(I)-A(I,I)
197      C BACKWARD IMPROVE
198      DO 30 I=NM1,2,-1
199      X(I)=A(I,N1)
200      DO 40 J=1,N
201      IF (I.NE.J).AND.(A(I,J).NE.0) X(I)=X(I)-A(I,J)+X(J)
202      X(I)=X(I)-A(I,I)
203      4 CONTINUE
204      C IMPROVE X(1) AND EXIT
205      NM1=A(1,N1)
206      DO 50 I=2,N
207      IF (A(I,I).NE.0) X(I)=1+X(I)-A(1,I)*X(I)
208      X(1)=X(1)-A(1,1)
209      RETURN
210      END
211      REAL FUNCTION DOCE(U,V,W,N,BF,EE,ETA,EXPO)
212      REAL E,F0(100),XY(4,100),BA(2),EA(2),D(2)
213      BA(1)=BF
214      BA(2)=BB
215      EA(1)=.25
216      EA(2)=ETA*.4
217      DO 1 I=1,2
218      D(I)=0
219      DO 2 I=1,N
220      U1=XY(1,I)-U*BA(I)
221      U2=XY(2,I)-U*BA(I)
222      V1=XY(3,I)-V*BA(I)
223      V2=XY(4,I)-V*BA(I)
224      D(K)=D(K)+(ERF(U2)-ERF(U1))+(ERF(V2)-ERF(V1))*EXPO(I)
225      2 CONTINUE
226      D(K)=D(K)*EA(K)
227      1 CONTINUE
228      DOCE=D(1)+D(2)
229      RETURN
230      END

```

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SAMPLE RUN OF PROXR

User inputs are preceded by >

>PROXR\_, PROXR  
ENTER BF,BB,ETA,ISO,IREF  
>.1 2.5 .9 4 1

BF= 0.10 BB= 2.5 ETA= 0.90 ISO= 4 NPEC= 4 IPEF= 1  
 X LOW X HIGH Y LOW Y HIGH EXP01 EXP02  
 -50.00 -35.00 0.00 15.00 1.10 1.00  
 0.00 15.00 0.00 15.00 1.09 0.99  
 16.00 17.00 0.00 15.00 1.40 1.28  
 18.00 19.00 0.00 15.00 1.55 1.41

ENTER 1 FOR WINDOW, 2 FOR LINE, OTHERWISE 0

>1

ENTER THE WINDOW EDGES X1,X2,Y1,Y2

>16 17 0 7.5

EDGES AT X= 16.00, 17.00 AND Y= 0.00, 7.50

		DOSE AT (X,Y)										
	Y=	0.00	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
X												
16.00		0.68	1.14	1.24	1.30	1.34	1.36	1.37	1.37	1.37	1.37	1.37
16.10		0.98	1.73	1.82	1.89	1.93	1.94	1.95	1.95	1.95	1.95	1.95
16.20		1.03	1.84	1.93	1.99	2.03	2.05	2.05	2.06	2.06	2.06	2.06
16.30		1.03	1.84	1.93	1.99	2.03	2.04	2.05	2.05	2.05	2.05	2.05
16.40		1.02	1.83	1.92	1.98	2.02	2.04	2.05	2.05	2.05	2.05	2.05
16.50		1.02	1.83	1.92	1.98	2.02	2.03	2.04	2.04	2.04	2.04	2.04
16.60		1.02	1.83	1.91	1.97	2.01	2.03	2.04	2.04	2.04	2.04	2.04
16.70		1.02	1.82	1.91	1.97	2.01	2.02	2.03	2.03	2.03	2.03	2.03
16.80		1.01	1.82	1.90	1.96	2.00	2.02	2.02	2.03	2.03	2.03	2.03
16.90		0.96	1.71	1.72	1.85	1.89	1.90	1.91	1.91	1.91	1.91	1.91
17.00		0.66	1.11	1.20	1.25	1.29	1.31	1.31	1.32	1.32	1.32	1.32

ENTER 1 FOR NEW WINDOW OR 0 TO CONTINUE

>0

ENTER 1 FOR WINDOW, 2 FOR LINE, OTHERWISE 0

>2

ENTER THE LINE END POINTS X1,Y1 X2,Y2

>10 7.5 20 7.5

P1=( 10.00 7.50) P2=( 20.00 7.50)

DOSE AT POINTS ON LINE										
	0	1	2	3	4	5	6	7	8	9
0	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06
10	2.06	2.06	2.05	2.05	2.05	2.05	2.05	2.04	2.04	2.04
20	2.03	2.03	2.03	2.02	2.02	2.01	2.01	2.00	2.00	1.99
30	1.98	1.98	1.97	1.96	1.95	1.95	1.94	1.93	1.92	1.91
40	1.91	1.90	1.89	1.88	1.87	1.86	1.85	1.84	1.83	1.74
50	1.28	0.81	0.72	0.71	0.70	0.70	0.69	0.68	0.68	0.78
60	1.37	1.95	2.06	2.05	2.05	2.04	2.04	2.03	2.03	1.91
70	1.32	0.72	0.61	0.60	0.59	0.58	0.58	0.57	0.56	0.67
80	1.32	1.96	2.07	2.06	2.05	2.03	2.02	2.01	1.99	1.86
90	1.19	0.52	0.39	0.37	0.36	0.34	0.32	0.31	0.29	0.28
100	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ENTER 1 FOR NEW LINE, 0 TO CONTINUE

>0

ENTER 1 FOR WINDOW, 2 FOR LINE, OTHERWISE 0

>0

ENTER 1 TO CONTINUE, 0 TO END

>0

STOP

END  
DATE  
FILMED  
4-82

DTIC